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Electron microscopy investigation of electrochemically enabled wetting of Y stabilized zirconia on Ni

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DTU Energy Conversion researches heavily in solid oxide fuel cell (SOFC) and solid oxide electrolysis cell (SOEC) technologies. Nickel and doped zirconia are fundamental materials used in both electrolysis and fuel cell electrodes. The two materials have been chosen for their materials properties and for the fact that they normally do not interact. In particular, it has been thought that nickel and zirconia do not wet each other, but quite unexpectedly we discovered how to unlock wettability in these materials, while studying the degradation process of SOEC-cells.

Durability and performance of an SOEC with a Ni/Y-stabilized zirconia composite cathode for high temperature co-electrolysis of steam and carbon dioxide was studied under high current density at 850°C for ~1200 h. Post mortem high resolution scanning electron microscopy revealed unusual zirconia nano particles located on Ni grains at the electrochemically active sites at the interface between the zirconia electrolyte and the active composite cathode. The nano particles appeared as islands intimately bonded on the surface of nickel particles (Figure 1). The presence and the shape of the zirconia nano particles indicated that a reaction had unlocked wettability in the two materials that under normal operating conditions would not react.

High resolution TEM study revealed that the mismatch between the lattice of the zirconia nano particles and the Ni grain was within 3%, and that an epitaxial relationship was formed between the new zirconia nano particles and the micrometer-scale Ni grains [1]. This can effectively reduce the interfacial energy and promote wettability.

The emergence of the zirconia nano particles is attributed to an electrochemical reduction of zirconia at the interface of the composite cathode and the electrolyte, followed by dissolution of zirconium in Ni, diffusion of Zr in the nickel particle to another location, where Zr oxidized at the surface, forming zirconia nano particles. The diffusion of zirconium through nickel is thought to be the key enabler for achieving epitaxy and thus unlocking the wettability of zirconia on the rough nickel surface.

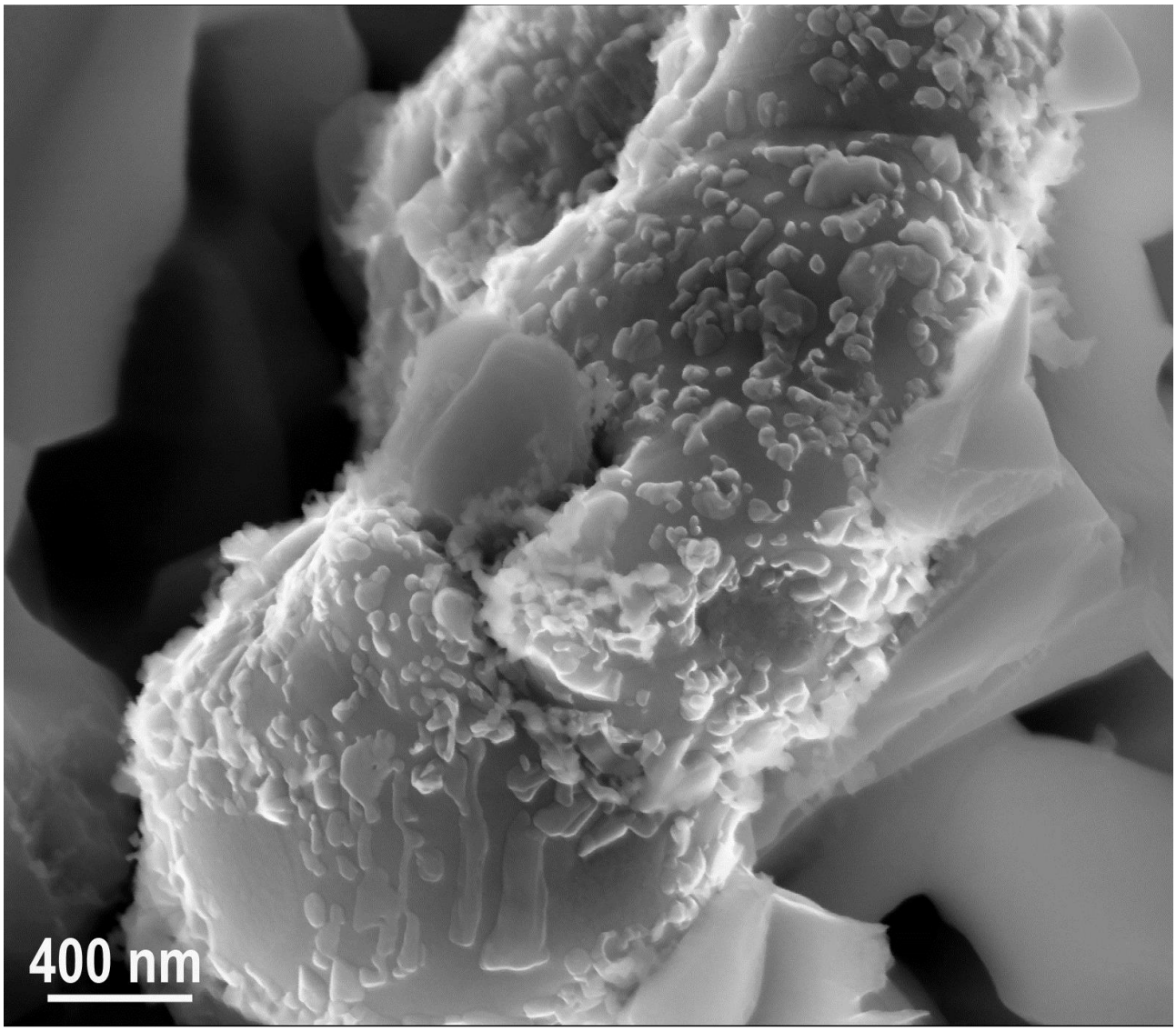

Fig. 1 Ni grains decorated with zirconia nano particles exhibiting well wetted morphology.

Reference

[1] Wei Zhang, Ming Chen, Luise Theil Kuhn, Jacob R. Bowen and Janet J. Bentzen, *ChemElectroChem*, 2014, vol.1, 520-523.